Content of amendment

(1) Claims 1 to 8 are amended as indicated on the separate sheet.

(2) Claims 9 to 18 are added as indicated on the separate sheet.

(3) The section of the specification from page 3, line 19 to page 4 line 13 stating "According to the present invention, ... the plurality of laser lights." is amended to: "According to the present invention, a method for cutting brittle material by irradiating laser light from a laser light source onto a brittle material to generate thermal distortions over a wide range of the brittle material, providing cracks in the interior of the brittle material and moving that irradiating position along a predetermined line of the brittle material to cut the brittle material, comprises providing a plurality of optical fibers which guide laser lights from a plurality of laser light sources to the brittle material; driving the plurality of laser light sources, with the plurality of optical fibers in a bundled condition such that irradiating spots of the lights irradiating the brittle material are arranged in a matrix arrangement, for irradiating a composite laser light which achieves a predetermined shape onto the surface of the brittle material; and adjusting a light intensity distribution of this composite laser light by controlling respectively the light intensity of the plurality of the laser light sources.

In this method, it is preferable to set the shape of the composite laser light by selectively driving the plurality of laser light sources.

Furthermore, it is also possible to set the shape of the composite laser light by selecting a method for bundling the plurality of optical fibers.

Moreover, it is also possible to set the plurality of laser light sources to different output intensities.

Furthermore, it is also possible to set the shape of the composite laser light by controlling an emission start time of the plurality of light sources to a predetermined sequence of time differences."

(4) The section of the specification from page 6, line 17 to page 7 line 1 stating "an apparatus ... onto the surface of the brittle material." is

amended to: "an apparatus suitable for carrying out the brittle material process method having the characteristics described above, in which laser light from a laser light source is irradiated onto the brittle material and that irradiating position is moved along a predetermined line, comprises a plurality of laser light sources; a plurality of optical fibers, bundled so as to guide the laser light from each laser light source to a surface of the brittle material, and arranged such that irradiating spots of the laser lights irradiating the brittle material are arranged in a matrix arrangement; and a scanning means for moving a position at which the laser light is irradiated onto the brittle material; wherein the composite laser light which has a predetermined shape is irradiated onto the surface of the brittle material with the plurality of bundled optical fibers, and the light intensity distribution of this composite laser light is adjusted by controlling respectively the light intensity of the plurality of laser light sources.

In this configuration, it is preferable to provide a light intensity measuring means for measuring a light intensity distribution of the composite laser light on the irradiated surface of the brittle material. Moreover, it is preferable to provide a transportation means for transporting the light intensity measuring means along the laser light irradiated surface of the brittle material."

accurate scribe line. It should be noted that in the processing method disclosed in Tokuhyo H8-509947 (Japanese Patent No. 3027768), there is also the problem that because a long time is required to heat the material interior to a sufficient temperature, cracks cannot be formed deep into the material within the heating times for scanning speeds that are used in practice.

In order to obtain a practically effective processing speed, examples have been disclosed which are realized by the addition of contrivances onto optical systems that are combinations of various lenses or optical parts, such as a laser beam emitted from the laser emitting portion arranged so as to widen in the scanning direction in an elliptical-shape or oval-shape, with the intention to have an irradiation area of laser light used in the process that is as wide as possible.

DISCLOSURE OF INVENTION

In view of the facts of the situation, an object of the present invention is to provide a method and an apparatus for processing brittle material at a fast process speed.

According to the present invention, a method for cutting brittle material by irradiating laser light from a laser light source onto a brittle material to generate thermal distortions over a wide range of the brittle material, providing cracks in the interior of the brittle material and moving that irradiating position along a predetermined line of the brittle material to cut the brittle material, comprises providing a plurality of optical fibers which guide laser lights from a plurality of laser light sources to the brittle material; driving the plurality of laser light sources, with the plurality of optical fibers in a bundled condition such that irradiating spots of the lights irradiating the brittle material are arranged in a matrix arrangement, for irradiating a composite laser light which achieves a predetermined shape onto the surface of the brittle material; and adjusting a light intensity

distribution of this composite laser light by controlling respectively the light intensity of the plurality of the laser light sources.

In this method, it is preferable to set the shape of the composite laser light by selectively driving the plurality of laser light sources.

Furthermore, it is also possible to set the shape of the composite laser light by selecting a method for bundling the plurality of optical fibers.

Moreover, it is also possible to set the plurality of laser light sources to different output intensities.

Furthermore, it is also possible to set the shape of the composite laser light by controlling an emission start time of the plurality of light sources to a predetermined sequence of time differences.

The operation of the processing method of the present invention is explained below.

If a brittle material is simultaneously irradiated with laser light from a plurality of laser light sources, the irradiating area that the laser light irradiates increases, the irradiating area of laser light on the surface of the brittle material to be processed greatly widens and the heated volume of the inside of the material that is heated per irradiated time increases. This generates thermal distortions across a wide range, and as a result of propagating at high speed cracks extending to deep regions, at the same time as moving the laser light in a predetermined direction relative to the surface of the brittle material, processing speed can be increased while scanning.

Moreover, by irradiating simultaneously low laser light from multiple laser light sources onto the brittle material, it is possible to use low output semiconductor lasers as the laser light source.

That is to say, the output strength of ordinary semiconductor lasers is low compared to gas lasers, and the output strength per single laser is insufficient, however by using a multitude of semiconductor lasers, and by

The position of each peak is expressed using three-dimensional coordinates. FIG. 3B on the other hand, shows schematically a condition in which the peak position of the central beam is shifted one step below the position of the lattice point peak position of other rows which are arranged in a uniform two dimensional plane. When the output of each beam is roughly the same, this condition corresponds to the case that when an attachment position of the output portion of the laser corresponding to the central row beam is shifted down. Furthermore, when the attachment position of the output portion of each beam is a lattice point arranged equidistantly in a two-dimensional planar shape, this also corresponds to the case that the output of the laser which corresponds to the central row beam is large.

Because of the above, by simultaneously irradiating the brittle material with laser light from more laser light sources it becomes possible to simultaneously irradiate the surface region over a wide area. The result of this is that a large volume of the internal portion of the brittle material can be simultaneously heated, and it is possible to increase the process speed.

According to the present invention, an apparatus suitable for carrying out the brittle material process method having the characteristics described above, in which laser light from a laser light source is irradiated onto the brittle material and that irradiating position is moved along a predetermined line, comprises a plurality of laser light sources; a plurality of optical fibers, bundled so as to guide the laser light from each laser light source to a surface of the brittle material, and arranged such that irradiating spots of the laser lights irradiating the brittle material are arranged in a matrix arrangement; and a scanning means for moving a position at which the laser light is irradiated onto the brittle material; wherein the composite laser light which has a predetermined shape is irradiated onto the surface of the brittle material with the plurality of bundled optical fibers, and the light intensity distribution of this composite laser light is adjusted by controlling respectively the light intensity of the plurality of laser light sources.

In this configuration, it is preferable to provide a light intensity measuring means for measuring a light intensity distribution of the composite laser light on the irradiated surface of the brittle material. Moreover, it is preferable to provide a transportation means for transporting the light intensity measuring means along the laser light irradiated surface of the brittle material.

According to the processing apparatus of the present invention, it can be confirmed whether the composite intensity distribution of the laser light which is irradiated onto the brittle material is attaining the desired intensity distribution, based on the output of the light intensity measuring means. Furthermore, when a plurality of laser light sources having different output intensities is used, the kind of intensity distribution that the composite intensity distribution obtains can be confirmed.

It should be noted that, by the irradiation of laser light from the laser light sources, the present invention is suitable for both a cutting process in which cracks are cut deep into the brittle material, and a cleaving process in which the brittle material is completely separated along a process line (scribe line) using only irradiation with laser light.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a diagram showing schematically a configuration of an embodiment of the present invention.

FIG. 2 is a diagram showing schematically a 2-D optical intensity distribution when laser light from a plurality of laser light sources irradiates a brittle material.

FIG. 3 is a diagram showing schematically a 3-D optical intensity distribution when laser light from a plurality of laser light sources irradiates a brittle material.

FIG. 4 is a diagram showing an example of a beam shape (viewed from above) which can be set when a plurality of laser light sources is used.

FIG. 5 is a diagram showing another example of a beam shape (viewed from above) which can be set when a plurality of laser light sources is used.

FIG. 6 is a diagram showing schematically the condition when only the surface vicinity of the brittle material is heated by laser light irradiation.